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COMPUTER PROGRAM USHL NO. 2

Water Surface Profiles for Spatially Varied Flow in Natural Channels

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COMPUTER PROGRAM USHL NO. 2
WATER SURFACE PROFILES FOR SPATIALLY VARIED FLOW IN NATURAL CHANNELS

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INTRODUCTION

The U.S. Hydrograph Laboratory of the Agricultural Research Service, working with the Central Technical Unit of the Soil Conservation Service, reviewed a number of existing hydraulic and hydrologic programs for IBM 1620 digital computers to see if any of them might be adapted to the watershed project formulation needs of the Soil Conservation Service and hydrologic research needs in ARS watersheds. A program developed by the U.S. Army Corps of Engineers [1] for computing water surface profiles by the step method [6] was selected and modified to spatially vary flow concordantly with drainage area, thus providing the profiles for selected flows-per-unit-area.

Spatial variations in flow and drastic differences in cross sections of the upland watershed streams used for trial runs caused the computed profiles to undulate unrealistically. A review of results indicated that undulations were greatest in reaches having steep slopes. As a result the program was further modified to interpolate hydraulic elements for theoretical cross sections at predetermined vertical intervals. Spatial variation of flow was also graduated by interpolating flow between cross sections in the ratio of the accumulative interval to the total interval of elevation. By these means the water surface profiles were stabilized in close conformity with profiles computed by more sophisticated techniques [3].

COMPUTER NEEDS

This program is adapted for a 1620 computer, 40K storage capacity with a card reader, a card punch, and an IBM 407 tabulating machine with an 80-80 control panel for listing punched output. This program is written in Fortran II.

PROGRAM FEATURES

The analytical procedure is basically an iterative solution of Bernoulli's Energy Theorem [5]. Solutions are obtained to the nearest 0.1 foot. Friction losses are obtained from Manning's formula. Bridge losses, bend losses, and contraction-expansion losses are determined by the entry of coefficients [2,7] at the appropriate cross sections.

Output from the program is a listing of water surface profile elevations for each csm assumed. By interrogating console sense switch No. 3, data for plotting storage indication curves will be computed and summarized in tabular form.

BASIC RELATIONS FOR COMPUTATIONS

Bernoulli's Theorem

$$E_1 = E_2 + hv_2 + h_f - hv_1$$

wherein:

E_1 is elevation water surface upstream end of reach, in feet;
hv_1 is velocity head upstream end of reach, in feet;
E_2 is elevation of water surface downstream end of reach, in feet;
hv_2 is velocity head downstream end of reach, in feet;
h_f is friction head loss, in feet.

Manning's Formula

$$h_f = \left(\frac{nQ}{1.486\ AR^{2/3}} \right)^2 \text{ x RCH}$$

wherein:

Q is discharge at section, in cubic feet per second;
A is cross-sectional area, in square feet;
R is hydraulic radius, in feet;
n is Manning's "n";
RCH is reach length, in feet.

Bridge Head Loss (from Yarnell [7] and Chow [2])

$$HBR = 2K\ (K + 10\omega - 0.6)\ (\alpha + 15\alpha^4)\ \frac{V^2}{2g}$$

wherein:

K is Yarnell's bridge coefficient (entered from Yarnell);
ω is ratio of the velocity head immediately downstream of bridge to the depth of flow through bridge (computed in program);
α is contraction ratio based on ratio of areas (computed in program);
V is velocity head in feet (computed in program);
g is acceleration due to gravity.

The values of K for the principal pier shapes tested by Yarnell [7] are listed below.

Semicircular nose and semicircular tail - - - -	0.90
Twin-circular piers with connecting diaphragm -	0.95
Twin-circular piers without diaphragm - - - - -	1.05
90° triangular nose and 90° triangular tail - -	1.05
Square nose and square tail - - - - - - - - - -	1.25

> "Piers with one or both ends lens-shaped or convex-shaped appear to have a coefficient very nearly the same as that for one with semicircular ends."

The following contraction and expansion loss coefficients [1] (SQZE) are suggested for use in the equation:

$$h_L = \text{SQZE} \left| \frac{V_1{}^2 - V_2{}^2}{2g} \right|$$

For converging reaches:

gradual convergence	0.10
abrupt convergence	0.50

For diverging reaches:

gradual expansion	0.20
abrupt expansion	0.50

Bend loss coefficients [4,8,9] (BEND) for use in the equation $h_L = \text{BEND}\ (V_1{}^2 + V_2{}^2 /\ 2g)$ can be computed as 0.20 (stream width/radius of curvature) for all bends 36° to 180°.

FIELD SURVEY FOR BASIC DATA

Many assumptions and averages of the hydraulic characteristics of a stream system are necessary to facilitate the computation of water surface profiles. Hence, it is important that the field survey document those features and changes in features of the stream and valley which tend to accelerate, retard, contract, or expand the flow of water.

The following should be observed in obtaining stream and valley cross sections.

1. Cross sections are needed at points where the stream flow gradient changes.
2. Cross sections are needed at points of contraction or expansion of the channel.
3. Cross sections are needed in tributaries immediately above

the confluence and in the mainstem immediately below the confluence.

4. Cross sections are needed to represent Manning's n, i.e., take sections so that there will be a uniform transition between sections, avoiding abrupt changes in n value whenever possible.
5. At bridges considered as controls, take cross sections at center of the bridge and immediately upstream and downstream of the bridge. (Sufficient field notes should be taken to determine Yarnell's bridge loss coefficient [2,7]).
6. Cross sections are required immediately above and below rated control sections, such as weirs, flumes, etc.
7. Distance between cross sections normally should not exceed one mile. Shorter reach lengths are required in areas of very steep bed slope. Determine both the channel and valley length between cross sections.
8. The horizontal reference must always be to the left of the first cross section coordinate point. The survey must be referenced consistently, either facing upstream or facing downstream.
9. Cross sections must extend vertically to exceed the anticipated elevation of the maximum flow profile to be computed.

DATA TABULATION

The spread sheet of Table 1 is a complete array of data needed at each cross section. The column numbers across the top of the table are in reference to the standard punch card and the numbers listed in column 80 are the serial numbers of the punch cards on which data and computations from the field survey are to be entered. This form is an instruction to the card punch operator but it also serves as a guide in the field survey. For example, cards numbered 3-10 indicate that coordinate points are limited to 32 for any one cross section. There are no limits concerning depressions on the flood plains, i.e., secondary channels may be topographically defined and will be included as part of overbank flow.

The lower portion of Table 1 provides information and parameter cards for eight additional profiles using the same cross section, depicted on cards 3-10. Information cards (No. 1) may differ in reach length (columns 7-11), and possibly in the loss coefficients (columns 20-28), for the various csm profiles. Parameter cards (No. 2) will differ in starting water surface elevation (columns 22-26) at the starting section only. The No. 2 cards remain the same for all profiles for cross sections above the starting section. However, they are duplicated for each profile to avoid confusion in machine loading.

Table 1.--Input Data, ARS-USHL #2: Water Surface Profile and Storage Indications

Watershed ____________________

Cross-Section Number ____________________

Engineer ____________________

Date ____________________

Columns: 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48 49 50 51 52 53 54 55 56 57 58 59 60 61 62 63 64 65 66 67 68 69 70 71 72 73 74 75 76 77 78 79 80

Elev. Intvl.	Flow rate, csm, for profile to be computed	Water Surface Slope[1]	Velocity Head[a]	[1]When starting at some intermediate section to continue computing the water surface profile, enter the water surface of the last computed section. When computing the profiles of tributaries, enter the water surface slope at the section in the main stem from which you are starting. [a]Same as [1] except enter velocity head. Note: Cols. 10-20 are left blank when starting the profile computations of main stem.	Flow rate csm	Card Number Identification
				PROFILE HEADER CARD (Entered at Starting Section only for given profile run)		0

Station Identification	Reach Length (feet)	Distance to left edge of channel	Distance to right edge of channel	Yarnell's Bridge Loss (k) coeff.	Bend Loss Coeff.	Contr.-Expan. Loss Coeff.	Invert Elevation of Bridge Outlet	CODE	Note: Code = 0 when no cross-section parameter card to be read. Code = 1 when cross-section parameter card to be read. All Data must be referenced facing upstream. The horizontal reference point must always be to the left of the first coordinate point in the cross-section.	Flow rate csm	Card Number Identification
									CROSS-SECTION INFORMATION CARD		1

Station Identification	Drainage Area (sq. miles)	Manning's n value: Left Bank	Manning's n value: Channel	Manning's n value: Right Bank	Starting Water Surface Elevation[1]	Time Increment for routing[2]	[1],[2]These cols. normally blank after first cross-section. Time interval for routing may be varied by entering a new increment at each section.	Flow rate csm	Card Number Identification
							CROSS-SECTION PARAMETER CARD		2

Station Identification	Data x-distance	Data Elevation	Data x-distance	Data Elevation	Data x-distance	Data Elevation	Data x-distance	Data Elevation	CODE	The top cross-section (upstream) must be identified as number one. The bottom (downstream) cross-section will be equal to the total number of cross-sections surveyed.	
											3
										STREAM-VALLEY CROSS-SECTION COORDINATE DATA (Maximum number of coordinates--32) Note: The last card containing coordinate data must have a 1 in Code Column. Preceding cards have 0 in Code Column.	4
											5
											6
											7
											8
											9
											10

SUBSTITUTE CROSS-SECTION INFORMATION AND PARAMETER CARDS FOR SUBSEQUENT PROFILE RUNS:

	CROSS-SECTION INFORMATION CARD	1
	CROSS-SECTION PARAMETER CARD	2
	CROSS-SECTION INFORMATION CARD	1
	CROSS-SECTION PARAMETER CARD	2
	CROSS-SECTION INFORMATION CARD	1
	CROSS-SECTION PARAMETER CARD	2
	CROSS-SECTION INFORMATION CARD	1
	CROSS-SECTION PARAMETER CARD	2
	CROSS-SECTION INFORMATION CARD	1
	CROSS-SECTION PARAMETER CARD	2
	CROSS-SECTION INFORMATION CARD	1
	CROSS-SECTION PARAMETER CARD	2
	CROSS-SECTION INFORMATION CARD	1
	CROSS-SECTION PARAMETER CARD	2
	CROSS-SECTION INFORMATION CARD	1
	CROSS-SECTION PARAMETER CARD	2

IMPORTANT: MACHINE OPERATOR. For each subsequent run at a different csm, re-punch a profile header card with the new csm rate in cols. 4-9 as indicated above. The order of input *must always* be as presented above.
KEY PUNCH OPERATOR. Decimals *are not* punched.

CARD PUNCHING

A list of symbols is given at the end of the text. The card column, format, and symbolic name of the associated data fields are given in Table 2. Data from Table 1 should be punched as follows:

1. Prepare only one profile header card for each water surface profile to be determined.

    (a) SLNEW and HVNEW columns will always be blank except when needed in (c).
    (b) EI is usually taken as 1 foot for a first trial.
    (c) SLNEW and HVNEW values are entered when determining water surface profiles for tributaries and when it is desired to finish a partially completed profile. Table 4 is an example of data prepared for a tributary with its confluence between cross sections 14 and 15 of the mainstem. The starting section was section 15 (mainstem). The SLNEW and HVNEW values were obtained from Table 6 (output data) in the Appendix.

2. Prepare one cross section information card for each profile at each cross section.

    (a) If there is no left overbank area, OBL must be algebraically less than the first x-distance, e.g., x-distance 100 feet; OBL may be 99 or less.
    (b) If there is no right overbank area, OBR must be algebraically greater than the longest x-distance.
    (c) Yarnell's bridge loss coefficients, bend loss coefficients, and contraction-expansion loss coefficients are taken from references [1,4,8, and 9].
    (d) Cross sections are identified (columns 1-4) with numeric characters beginning with one for the upstream section.
    (e) Streams are identified (columns 5-6) with two alphabetic characters (e.g. SB for South Branch).

3. Prepare one cross section parameter card for each profile at each cross section.

    (a) When possible the starting water surface elevation for a given csm is obtained from existing rating curves.
    (b) For resumed computations or for tributary profiles, given in step 1(c), the starting ELEV becomes the elevation previously computed for that water surface profile at that section (cross section 15 of example).

TABLE 2.--Input Data Card Format*

Profile Header Card:

1-3	4-9	10-16	17-20
X.XX	XXXXXX.	.XXXXXXX	XX.XX
EI	CSM	SLNEW	HVNEW

Note: The profile header card is coded with a zero in column 80.

Cross Section Information Card:

1-4	5-6	7-11	12-15	16-19	20-22	23-25	26-28	29-33	34
XXXX	XX	XXXXX.	XXXX.	XXXX.	X.XX	X.XX	X.XX	XXXX.X	X.
NSTA	LET	RCH	OBL	OBR	YARK	BEND	SQZE	EVRT	FLAG

Note: The cross section information card is coded with a 1 in column 80.

Cross Section Parameter Card:

1-4	5-6	7-12	13-15	16-18	19-21	22-27	28-31
XXXX	XX	XXXX.XX	.XXX	.XXX	.XXX	XXXX.XX	XX.XX
NSTA	LET	DA	C(1)	C(2)	C(3)	ELEV	DT

Note: The cross section parameter card is coded with a 2 in column 80.

Valley Cross Section Coordinate Data:

1-4	5-6	7-11	12-16	17-21	22-26	27-31	32-36	37-41	42-46	47
XXXX	XX	XXXX.X	XXXX.X	XXXX.X	XXXX.X	XXXX.X	XXXX.X	XXXX.X	XXXX.X	X.
NSTA	LET	X(I)	Y(I)	X(I+1)	Y(I+1)	X(I+2)	Y(I+2)	X(I+3)	Y(I+3)	EX

Note: Valley cross section coordinate data cards (Maximum of 8) are coded from 3-10 in column 80.

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*Symbols are taken from list of program symbols given at the end of the text.

(c) DT must always be entered for the first downstream cross section if storage indication data are desired. DT entries are required for subsequent sections only if routing time is to be varied.

4. Only one set of valley cross section coordinate data is needed. Table 3 in the Appendix illustrates the data required for determining the 10 csm water surface profile of Fall River, Kansas. To determine other profiles replace card types 0, 1, and 2; these are the substitute cards of Table 1. An abbreviated example of input data for a tributary profile is given in Table 4 of the Appendix. Table 5 illustrates input data for a bridge section.

OPERATING INSTRUCTIONS

1. Load object deck with library floating point subroutines (Fortran II).
2. Turn switch 3 on for storage indication data.
3. Check to see that order of input corresponds with that of Table 1 or Table 3.
4. For the first section all three control cards (card types 0, 1, 2) must be present in the order 0, 1, 2.
5. For subsequent sections in the same profile run, only two control cards are needed (1,2). A card type 2 is not required when a zero appears in column 34 of card type 1.
6. When stacking a new profile run key-punch a new profile header card.
7. Substitute card types 1, 2 with the new control cards for the next csm.
8. At the completion of a profile sort storage indication data from water surface profile data. Storage indication data are coded with a 1 in column 80.
9. Exceeds survey: When the survey bounds are exceeded the instruction EXCEEDS SURVEY LIMITS (section at which boundaries were exceeded) TURN SW 1 ON FOR RERUN WITH SHORTER REACH LENGTH OFF CONTINUES UPSTREAM is typed by the typewriter. Check the EI interval. Turn SW 1 on and push start. Enter one-half the previous EI value by typewriter with format X.XX. Turn SW 1 off to revert to automatic selection of EI. If the water surface again exceeds survey for the cross section, leave SW 1 off and push start to continue with the next cross section.
10. Partially completed profile: When a profile has not been completed due to machine failure or other, the profile may be continued at the computed section by key punching new card types 0, 1, 2 for the last cross section at which the water

surface elevation has been determined. Enter the same data as required for tributary profiles (Table 4). The new values to be punched are: SLNEW, HVNEW (card type 0), RCH=0 (card type 1), and ELEV, DT (card type 2).

OUTPUT DATA

An example of output data is given in Table 6. This output resulted from the input data of Table 3. Flow through each section is given in cfs; starting water surface elevation is given in feet and Manning's n values are for left overbank, channel, and right overbank areas, respectively.

Starting at cross section 22W with reach length (RCH=0) the data, from left to right, are coded as follows:

1st line:	Code	Example (Table 6)
	1. NSTA, LET	22W
	2. SLOPE	0.0007845
	3. V(1)	0.00
	4. V(2)	3.42
	5. V(3)	0.00
	6. HV1	0.18
	7. ECOMP	989.80
2nd line:	1. HFRIC	0.00
	2. A(1)	0.
	3. A(2)	926.
	4. A(3)	0.
	5. BENO	0.00
	6. EWS	989.80
3rd line:	1. R(1)	0.00
	2. R(2)	7.05
	3. R(3)	0.00
	4. SQZO	0.00

It is suggested that a clear plastic overlay be made for easy identification of water surface profile output data.

An example of storage indication data is given in Table 7 of the Appendix. These data were also derived from the input data given in Table 3 of the Appendix. The data appearing in the columns headed by S and (O/2 + S/DELT) are given as a power of 10, e.g. the first value under S is .38522213 E + 04, which is equal to 3852.2213. If the exponent +04 had been -04, then the decimal would be moved four places to the left or .00003852213.

The area given in the last data column is the cross-sectional area of flow. It is listed for use with flow rate to derive the average velocity of flow, sometimes required for deriving travel time or coefficients for certain types of flood routing.

SYMBOLS USED IN THE PROGRAM

Symbol	Description
Input:	
BEND	Bend loss coefficient.
C(I) I=1,3	Manning's n for left overbank, channel, and right overbank areas, respectively.
CSM	The flow rate in csm at which water surface profile is to be determined.
DA	Drainage area above cross section in square miles.
DT	Routing time increment in hours.
EI	Elevation increment. This value determines the number of subdivisions between cross sections.
EINT	EI (may be entered by typewriter).
ELEV	Starting water surface elevation.
EVRT	Invert elevation immediately downstream of bridge.
EX	One digit integer having the value of 0 or 1. 0 if more coordinate data for given cross section to be read. 1 if last card of coordinate data.
FLAG	One digit integer having the value of 0 or 1. 0 if no cross section parameter to follow. 1 if cross section parameter card to follow.
HVNEW	Velocity head of cross section from which tributary profile computations begin.
LET	Stream or river identification. Two characters of the alphabet may be used.
NSTA	Cross section identification - all cross sections must have a numeric designation beginning with one for the upstream section.

SYMBOLS USED IN THE PROGRAM (Continued)

Symbol	Description
OBL	Distance from horizontal reference point to left-most edge of stream channel.
OBR	Distance from horizontal reference point to right-most edge of stream channel.
RCH	Reach length - distance between cross sections.
SLNEW	Water surface slope of the cross section from which tributary profile begins.
SQZE	Contraction - expansion loss coefficient.
X(I) I=1,32	x-distance (horizontal distance from reference to the coordinate points in the cross section).
Y(I) I=1,32	Elevation of coordinate points (normally referenced to mean sea level).
YARK	Yarnell's bridge loss coefficient.
Output:	
A(I) I=1,3	Area of left overbank, channel, and right overbank, respectively.
A1	Area of cross section being processed.
A2	Area of last cross section analyzed.
BENO	Bend head loss.
C(I) I=1,3	See input.
DELT	Routing time interval (hrs.) - DT
ECOMP	Computed water surface elevation.
ELEV	See input.
EWS	Estimated water surface elevation.
FLOW	Flow rate (cfs).
FLOW1	Flow rate (cfs) at last cross section analyzed.

SYMBOLS USED IN THE PROGRAM (Continued)

Symbol	Description
FLOW2	Flow rate (cfs) at cross section being processed.
HBR	Bridge head loss.
HFRIC	Friction head loss.
HV1	Velocity head at section being analyzed.
KODE	Code 1 punched in column 80.
LET	See input.
NCSM	Flow rate in csm.
NSTA	See input.
NSTAO	Cross section identification of last section analyzed.
R(I) I=1,3	Hydraulic radius of left overbank, channel, and right overbank, respectively.
RCH	See input.
ROF1	FLOW1/2 + S/DELT
S	Storage between cross sections (cfs-hrs.).
SLOPE	Water surface slope.
SQZO	Expansion-contraction head loss.
V(I) I=1,3	Average velocity (ft/sec) of left overbank, channel, and right overbank respectively.

Main Program:

Symbol	Description
AA(I) I=1,3	Area of left overbank, channel, and right overbank of last section analyzed.
ALFA	Channel constriction ratio.
AL4	ALFA raised to the 4th power.
AN	A count of the number of intermediate cross sections processed.
AREA	Sub-program for determining the area of cross sections.

SYMBOLS USED IN THE PROGRAM (Continued)

Symbol	Description
ASUM	Sum of the left overbank, channel, and right overbank areas, respectively.
AVGA	Average of two end areas.
CC(I) I=1,3	Manning's n of the left overbank, channel, and right overbank for the last cross section analyzed.
CFAC	Number of reach sub-divisions between cross sections.
CHE	Elevation difference between cross sections.
CHB	Elevation of channel bottom at cross section being processed.
CHBO	Elevation of channel bottom at last cross section processed.
DELHV	Difference in velocity heads between two cross sections.
DELQ(I) I=1,3	$\frac{0.01486\ A(I)\ R(I)^{2/3}}{n(I)}$, or discharges based on $S^{\frac{1}{2}} = 0.01$.
ECOMO	Elevation of water surface at last cross section analyzed.
ECOMOO	ECOMO
ETEST	Test for balance of energies.
EWS2	Estimated water surface elevation for intermediate sections.
HVO	Velocity head at last section processed.
I	Index of do loop.
II	I+3 (determines upper limit of read loop).
J	Index of do loop.
JJ	Index code having the value of 0 or 1. 0 if channel elevation to be determined. 1 if channel bottom elevation for given section has been determined.
K	Index code having the value of 1 or 2. 1 for first cross section and bridge computations. 2 for remainder of given profile analyses.

SYMBOLS USED IN THE PROGRAM (Continued)

Symbol	Description
LL	Index code having the value of 0, 1, or 2. 0 to continue on normal flow path. 1 for shorter reach length, then branch back to beginning of section computations. 2 to proceed to next section (beyond survey bounds).
LN	Index code having the value of 0, 1. 0 if elevation difference is not to be determined. 1 if elevation difference to be determined.
LN1	Index code having the value of 0 or 1. 0 for first cross section. 1 for subsequent sections.
M	I+3 (determines upper limit of search loop).
N	Counts number of coordinates per cross section.
NPASS	Index code - counts number of times estimated water surface exceeds survey bounds.
NSECS	CFAC
OMEGA	Velocity head immediately downstream of bridge divided by depth of water immediately downstream of bridge.
P(I) I=1,3	Wetted perimeter of left overbank, channel, and right overbank, respectively.
QSUM	Sum of DELQ(I).
RATIO	Ratio of discharge for which water surface profile is being computed to a discharge based on $S^{\frac{1}{2}} = 0.01$.
RCHO	Distance between two given cross sections.
RR(I) I=1,3	Hydraulic radius of last computed cross section.
SCH	Channel slope.
SLOPO	Water surface slope at last computed section.
SLOPOO	SLOPO (before intermediate sections).
SUMVQ	Sum of products of velocities squared times discharges for left overbank, channel, and right overbank, respectively.

SYMBOLS USED IN THE PROGRAM (Continued)

Symbol	Description
V2Q(I) I=1,3	V^2Q for left overbank, channel, and right overbank, respectively - used to determine weighted average of stream velocity.
YDELO	Elevation of preceding coordinate point.
Sub-program:	
A(I) I=1,3	See output.
AN	See main program.
AREA	See main program.
B	Horizontal distance between coordinate points.
C	Vertical distance between coordinate points.
D,E,G,H	Arguments of arithmetic function statements.
EVRT	See input.
EWS	See output.
EWS2	See main program.
I	Index of do loop.
J	Index code having value of 1, 2, or 3. 1 for left overbank, 2 for main channel, and 3 for right overbank.
K	Index code for routing to correct arithmetic function statement.
LET	See input.
LL	See main program.
LM	Index code for determining limits of EWS2 when estimate exceeds survey bounds.
N	See main program.
NPASS	See main program.

SYMBOLS USED IN THE PROGRAM (Continued)

Symbol	Description
NSTA	See input.
OBL	See input.
OBR	See input.
P(I) I=1,3	See main program.
RCH	See input.
RCHO	See main program.
SCH	See main program.
SLOPOO	See main program.
X(I) I=1,32	See input.
XWS	Distance from horizontal reference point to edge of water surface.
Y(I) I=1,32	See input.
YDEL	Depth of water at coordinate point being processed.
YDELO	See main program.

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APPENDIX FOLLOWS

APPENDIX

TABLE 3. INPUT DATA FOR DETERMINING THE WATER SURFACE PROFILE OF THE MAIN STEM OF UPPER FALL RIVER, KANSAS AT A FLOW OF 10 CSM.

```
100000010                                                                      0
0022 W0000030163185000000000000001                                    10       1
0022 W0317380620450500989800025                                       10       2
0022 W00000100630145010024025101000705350099960                                3
0022 W07930099661185009991138500999416200099900                                4
0022 W20050099872975009986301000998530160099360                                5
0022 W30350098873045009813315000982031600099700                                6
0022 W31850100253220010027345501004840400100641                                7
0021 W1510032003520000000000000001                                    10       1
0021 W03107306204507000000                                            10       2
0021 W00000103580050010325022501022304050101810                                3
0021 W07900101690920010168115001016311600101600                                4
0021 W11850101211325010123149501014716650101830                                5
0021 W22700101912510010199277001020431300102130                                6
0021 W32000101933280010103333501008833500100350                                7
0021 W33800099403475009943348501011435150101680                                8
0021 W35200102103865010229409501023443550102510                                9
0021 W45550102735120010296521001033253100105091                               10
0020 W1050054805680000000000000001                                    10       1
0020 W03042405805005000000                                            10       2
0020 W00600104690540010426064001041208200103650                                3
0020 W09650103541555010347179501032920550103260                                4
0020 W24150103102930010288303501028333500103130                                5
0020 W38550103034285010271483501027449550102750                                6
0020 W50250102885155010264530501023753700102310                                7
0020 W54700101915480010176550001013055200100050                                8
0020 W56100100105615010110562501014256400101900                                9
0020 W5680010469                              1                               10
0019 W0520050355209000000000000001                                    10       1
0019 W02986806304506000000                                            10       2
0019 W00400105520390010509073001047108600104380                                3
0019 W13700104011430010400184001037921150103770                                4
0019 W21700103632325010330267001034827550103880                                5
0019 W36100103623755010333427501034544300102970                                6
0019 W46400102764735010254483501025349350102370                                7
0019 W50350102635065010182509001010451600101030                                8
0019 W51700101745185010226520001034852090103600                                9
0019 W551001037657500104195915010560          1                               10
0018 W0800004450675000000000000001                                    10       1
0018 W02118406005006000000                                            10       2
0018 W00000105650220010507040501049204250104630                                3
0018 W04450104270475010359048001026506200102610                                4
0018 W06300103600675010410079001037511000104040                                5
0018 W13700104451490010480156001048217550104720                                6
0018 W216001047923150104842365010584          1                                7
0017 W06800-110035400000000000000001                                  10       1
0017 W02092800005505000000                                            10       2
0017 W00000106980015010671008501045701800104500                                3
0017 W02150104430230010402033501040103450105100                                4
0017 W03540105540360010550048001054105550105580                                5
0017 W07200105740721010576092001048515800104890                                6
0017 W17400105002080010564235001056525400105550                                7
0017 W30750105543250010539338001054335650105480                                8
0017 W373001057239000106154040010707          1                                9
0016 W1330024602660000000000000001                                    10       1
0016 WC2050005006000000000                                            10       2
0016 W00000108430025010779005001073601300106850                                3
```

```
      TABLE 3.  (CONTINUED)

0016 W03800106961195010698139501068719250106810                                 4
0016 W21650106472430010625246001061824850105430                                 5
0016 W25050104372595010441260001051426550108971                                 6
0015 W08000110512500000000000000001                                   10        1
0015 W01930307907010000000                                            10        2
0015 W00800108650135010822017501078902050107580                                 3
0015 W04450107550585010754072001071608250107150                                 4
0015 W09150106960985010673102001069511050107110                                 5
0015 W11250106871130010658114501057212250105770                                 6
0015 W12300106281250010748129001073814250107360                                 7
0015 W14700107171570010839160001087000000000001                                 8
0014 W10400182520100000000000000001200                                10        1
0014 W01097905000000000000                                            10        2
0014 W00000111410140011047020001104503000110310                                 3
0014 W04600109970570010970071501096307850109510                                 4
0014 W08100109460850010961092501097511100109760                                 5
0014 W12900109631385010949146501093415500109050                                 6
0014 W17150109031745010895178001087718250108520                                 7
0014 W18350108311857010753192201075519270107870                                 8
0014 W194201085619620109902007011170          1                                 9
0013 W08300061507200000000000000001200                                10        1
0013 W01040307507006500000                                            10        2
0013 W00000112120135011160028501115706150111340                                 3
0013 W06350109760640010969065501087707000108780                                 4
0013 W07100108860720010972083501100708700110370                                 5
0013 W15000109781550010979175001104620900110230                                 6
0013 W23100109872540011020327001108136000112121                                 7
0012 W04700130514240000000000000001200                                10        1
0012 W00979908306504500000                                            10        2
0012 W00000112600050011239025001117204150111340                                 3
0012 W06950111321000011125104501107711500110420                                 4
0012 W12300110411305011026132001099713220109220                                 5
0012 W13820109291410011088142401113917000111410                                 6
0012 W26200111492770011156326001116239700111660                                 7
0012 W40500111824290011222446001125347050112951                                 8
0011 W11300-11002560000000000000001200                                10        1
0011 W00946400007005000000                                            10        2
0011 W01100113790140011266015501119701700111580                                 3
0011 W01740110770240011081025201120302560112340                                 4
0011 W02950112310370011273058501128507100112890                                 5
0011 W08650113061070011315142001133817300113981                                 6
0010 W09300370541600000000000000001200                                10        1
0010 W00878106007200000000                                            10        2
0010 W01300116970295011667052001163008400116100                                 3
0010 W09900116001410011583181001155521800115340                                 4
0010 W23800115242840011511307001150332600114870                                 5
0010 W34900114693510011468352001145937050114650                                 6
0010 W37450113703757011351381501135038250114360                                 7
0010 W38400114593880011529399001160840650116610                                 8
0010 W4150011729                              1                                 9
0009 W05900181020500000000000000001200                                10        1
0009 W00572107108500000000                                            10        2
0009 W00000117570200011715057001164808500116080                                 3
0009 W10700115801140011571132501155113700115660                                 4
0009 W15100115801525011568163001153817000115370                                 5
0009 W17150115201810011533182001151918250114420                                 6
0009 W18780114381895011513190501157620450118581                                 7
```

TABLE 3. (CONTINUED)

```
0008 W0600009951218000000000000001200                                 10        1
0008 W00536810508515000000                                            10        2
0008 W00600118800145011802017501178303150117600                                 3
0008 W04250117490620011716069501167807650116870                                 4
0008 W08050116930855011667090501166609350116600                                 5
0008 W09950116591015011634109501161311350116100                                 6
0008 W11750116091200011591121301159012180117340                                 7
0008 W12240117331244011734127401176014090117850                                 8
0008 W1429011880                              1                                 9
0007 W0370010251140000000000000001200                                 10        1
0007 W00388604007015000000                                            10        2
0007 W00000121140150012064020001198103400119310                                 3
0007 W04150119010171011881091001187109800118320                                 4
0007 W10100118111025011797107001174911050117100                                 5
0007 W11350117111140011762121001176412550117650                                 6
0007 W12650118181270011889129501199613100121141                                 7
0006 W03700-110015400000000000000001200                                 10        1
0006 W00361800006504000000                                            10        2
0006 W00000121160055011980007001191000850118220                                 3
0006 W01500118210154011913017501188802200119060                                 4
0006 W02600119400470011944071001194510100119570                                 5
0006 W104001201310650120621090012116          1                                 6
0005 W0690004100530000000000000001100                                 10        1
0005 W00349708205507000000                                            10        2
0005 W00000123200030012309008001228201400122370                                 3
0005 W02300122150290012213032501220003800121680                                 4
0005 W03950121780410012183043301211904630120900                                 5
0005 W05050120910511012098051701219805300122210                                 6
0005 W05500122260630012227070501224408800122650                                 7
0005 W108501229511350123111205012333          1                                 8
0004 W0510003950535000000000000001100                                 10        1
0004 W00245307505007500000                                            10        2
0004 W02750124850310012473034501244203700123660                                 3
0004 W03950123460405012285046501228604950123070                                 4
0004 W05150123330535012356058001236608350123670                                 5
0004 W10500123851145012400121501243012750124650                                 6
0004 W1350012498                              1                                 7
0003 W03900-110028000000000000000001100                                 10        1
0003 W00232900006004000000                                            10        2
0003 W00500126350095012561014001252601830124860                                 3
0003 W01850124510243012450026001248602700125520                                 4
0003 W02800125610325012568048001256306500125610                                 5
0003 W08500125601040012553139001253815300125370                                 6
0003 W16900125681755012635                    1                                 7
0002 W06500-110016500000000000000001100                                 10        1
0002 W00138700006006500000                                            10        2
0002 W00350130300065012853007801274501180127440                                 3
0002 W01250127780145012792016501282202150128230                                 4
0002 W02450128390450012843060001285107200128540                                 5
0002 W08000128671050012874108001288911000130301                                 6
0001 W0800008651020000000000000001100                                 10        1
0001 W00103805005500000000                                            10        2
0001 W00000133240055013272037001321305950131890                                 3
0001 W06300131810865013175088001315608900131220                                 4
0001 W09150131230920013160093001318809400132540                                 5
0001 W09600132921015013324                    1                                 6
```

TABLE 4. INPUT DATA FOR DETERMINING THE WATER SURFACE PROFILE OF A TRIBUTARY TO THE MAIN STEM OF UPPER FALL RIVER, KANSAS AT A FLOW OF 10 CSM.

```
10000001000108100016                                                  10       0
0015 W0800011051250000000000000001                                    10       1
0015 W01930307907010000000                                            10       2
0015 W00800108650135010822017501078902050107580                                3
0015 W04450107550585010754072001071608250107150                                4
0015 W09150106960985010673102001069511050107110                                5
0015 W11250106871130010658114501057212250105770                                6
0015 W12300106281250010748129001073814250107360                                7
0015 W14700107171570010839160001087000000000001                                8
0013EB0950006350785000000000000001                                    10       1
0013EB0077800500450450000000000001                                    10       2
0013EB00000110480050010986007001096201350109330                                3
0013EB02250109210330010901039501091306350109280                                4
0013EB06550108230670010763067501073707500107350                                5
0013EB07600107920785010828083001084209200108590                                6
0013EB10250108631100010900135501090115400109090                                7
0013EB16600109221865010928222501093124100109380                                8
0013EB27950109462885010953301001099730850110130                                9
0013EB32000110263400011048                    1                               10
0012EB10000-11003630000000000000001                                   10       1
0012EB0071900000500500000000000001                                    10       2
0012EB00000112380180011129020001108502300109490                                3
0012EB02400108940300010892032001096903630109910                                4
0012EB04300109950555011006073501104410200110220                                5
0012EB11100110281170011051120001106013650110650                                6
0012EB13750110581695011013179501101018050110140                                7
0012EB19100110512090011075232501109924150111020                                8
0012EB27750111033460011107362501112139450111500                                9
0012EB4400011238                              1                               10
```

TABLE 5 . INPUT DATA FOR DETERMINING THE BACKWATER EFFECT OF A BRIDGE.
DATA FROM UPPER FALL RIVER, KANSAS

```
100000010                                                                10       0
0022 W000003016318500000000000000001                                     10       1
0022 W0317380620450500989800025                                          10       2
0022 W00000100630145010024025101000705350099960                                   3
0022 W07930099661185009991138500999416200099900                                   4
0022 W20050099872975009986301000998530160099360                                   5
0022 W30350098873045009813315000982031600099700                                   6
0022 W31850100253220010027345501004840400100641                                   7
0022BW000004120460009000000000099051                                     10       1
0022BW031405062045010                                                    10       2
0022BW00000103250580010295091001021515800102000                                   3
0022BW16200100201660009985168000998317200101200                                   4
0022BW19000102002500010170310001017541200102600                                   5
0022BW42050099054280009910430500993044100099400                                   6
0022BW44800099554600010257556001020570100102040                                   7
0022BW750001021078000102258240010330             1                                8
0021 W151003200352000000000000000001                                     10       1
0021 W03107306204507000000                                               10       2
0021 W00000103580050010325022501022304050101810                                   3
0021 W07900101690920010168115001016311600101600                                   4
0021 W11850101211325010123149501014716650101830                                   5
0021 W22700101912510010199277001020431300102130                                   6
0021 W32000101933280010103333501008833500100350                                   7
0021 W33800099403475009943348501011435150101680                                   8
0021 W35200102103865010229409501023443550102510                                   9
0021 W45550102735120010296521001033253100105091                                  10
```

TABLE 6 WATER SURFACE PROFILE MACHINE OUTPUT
FOR 10 CSM FLOW UPPER FALL RIVER, KANSAS

```
   10 CSM PROFILE


      FLOW    3173.      STARTING W.S. ELEV.   989.80
      N VALUES     .062  .045  .050
RCH=     0.
   22 W      .0007845     0.00     3.42     0.00      .18      989.80
        0.00              0.       926.     0.        0.00     989.80
                          0.00     7.05     0.00      0.00
      FLOW    3107.
      N VALUES     .062  .045  .070
RCH= 15100.
   21 W      .0008551     0.00     3.48     0.00      .18     1002.22
        1.07              0.       891.     0.        0.00    1002.22
                          0.00     6.78     0.00      0.00
      FLOW    3042.
      N VALUES     .058  .050  .050
RCH= 10500.
   20 W      .0006001     0.00     3.23     0.00      .16     1010.11
        1.07              0.       940.     0.        0.00    1010.13
                          0.00     7.93     0.00      0.00
      FLOW    2986.
      N VALUES     .063  .045  .060
RCH=  5200.
   19 W      .0025314     0.00     5.20     0.00      .42     1017.07
        1.44              0.       573.     0.        0.00    1017.06
                          0.00     5.51     0.00      0.00
      FLOW    2118.
      N VALUES     .060  .050  .060
RCH=  8000.
   18 W      .0018665     0.00     3.56     0.00      .19     1030.45
         .98              0.       593.     0.        0.00    1030.44
                          0.00     3.94     0.00      0.00
      FLOW    2092.
      N VALUES    0.000  .055  .050
RCH=  6800.
   17 W      .0022843     0.00     3.45     0.00      .18     1045.21
        1.09              0.       606.     0.        0.00    1045.18
                          0.00     3.22     0.00      0.00
      FLOW    2050.
      N VALUES     .050  .060 0.000
RCH= 13300.
   16 W      .0001375     0.00     1.70     0.00      .04     1055.26
         .87              0.      1204.     0.        0.00    1055.31
                          0.00     9.13     0.00      0.00
      FLOW    1930.
      N VALUES     .079  .070  .100
RCH=  8000.
   15 W      .0025612     0.00     4.51     0.00      .31     1062.32
        1.63              0.       427.     0.        0.00    1062.37
                          0.00     4.41     0.00      0.00
      FLOW    1097.
      N VALUES     .050  .060 0.000
RCH= 10400.
   14 W      .0016101     0.00     3.26     0.00      .16     1079.89
         .92              0.       336.     0.        0.00    1079.88
                          0.00     3.84     0.00      0.00
```

```
  TABLE  6    (CONTINUED)
      FLOW    1040.
      N VALUES     .075   .070   .065
RCH=  8300.
   13 W      .0014826     0.00    3.37    0.00     .17    1092.84
          1.02            0.      307.    0.      0.00    1092.84
                          0.00    4.31    0.00    0.00
      FLOW     979.
      N VALUES     .083   .065   .045
RCH=  4700.
   12 W      .0007784     0.00    2.62    0.00     .10    1098.25
            .93           0.      373.    0.      0.00    1098.27
                          0.00    4.84    0.00    0.00
      FLOW     946.
      N VALUES   0.000    .070   .050
RCH= 11300.
   11 W      .0014732     0.00    3.13    0.00     .15    1112.26
          1.11            0.      302.    0.      0.00    1112.27
                          0.00    3.92    0.00    0.00
      FLOW     878.
      N VALUES     .060   .072 0.000
RCH=  9300.
   10 W      .0030261     0.00    3.67    0.00     .21    1138.46
          1.04            0.      238.    0.      0.00    1138.46
                          0.00    2.91    0.00    0.00
      FLOW     572.
      N VALUES     .071   .085 0.000
RCH=  5900.
    9 W      .0011527     0.00    2.50    0.00     .09    1147.89
            .81           0.      228.    0.      0.00    1147.86
                          0.00    3.38    0.00    0.00
      FLOW     536.
      N VALUES     .105   .085   .150
RCH=  6000.
    8 W      .0024488     0.00    2.12    0.00     .07    1162.48
          1.06            0.      252.    0.      0.00    1162.49
                          0.00    1.50    0.00    0.00
      FLOW     388.
      N VALUES     .040   .070   .150
RCH=  3700.
    7 W      .0034720     0.00    3.13    0.00     .15    1173.83
          1.07            0.      123.    0.      0.00    1173.84
                          0.00    2.07    0.00    0.00
      FLOW     361.
      N VALUES   0.000    .065   .040
RCH=  3700.
    6 W      .0029596     0.00    2.70    0.00     .11    1184.14
            .99           0.      133.    0.      0.00    1184.14
                          0.00    1.87    0.00    0.00
      FLOW     349.
      N VALUES     .082   .055   .070
RCH=  6900.
    5 W      .0040078     0.00    2.91    0.00     .13    1211.12
          1.04            0.      119.    0.      0.00    1211.10
                          0.00    1.67    0.00    0.00
      FLOW     245.
      N VALUES     .075   .050   .075
  TABLE  6   (CONTINUED)
RCH=  5100.
    4 W      .0036775      0.00     2.31     0.00       .08     1230.01
          1.01             0.     105.       0.        0.00     1230.03
                           0.00     1.26     0.00      0.00
      FLOW      232.
      N VALUES   0.000   .060   .040
RCH=  3900.
    3 W      .0041448      0.00     2.57     0.00       .10     1246.49
          1.02             0.       90.      0.        0.00     1246.50
                           0.00     1.35     0.00      0.00
      FLOW      138.
      N VALUES   0.000   .060   .065
RCH=  6500.
    2 W      .0045985      0.00     2.52     0.00       .09     1275.74
          1.04             0.       54.      0.        0.00     1275.75
                           0.00     1.21     0.00      0.00
      FLOW      103.
      N VALUES    .050   .055 0.000
RCH=  8000.
    1 W      .0047852      0.00     2.61     0.00       .10     1313.62
           .94             0.       39.      0.        0.00     1313.66
                           0.00     1.24     0.00      0.00
```

TABLE 7 STORAGE INDICATION MACHINE OUTPUT

```
STATION   CFS          S               DELT (O/2 + S/DELT)        AREA                        1
  22 W   3173.  .38133369E+04      .25  .16840247E+05          926.                        1
  21 W   3107.  .26715885E+04      .25  .12240004E+05          891.                        1
  20 W   3042.  .10933095E+04      .25  .58944380E+04          940.                        1
  19 W   2986.  .12969896E+04      .25  .66813584E+04          573.                        1
  18 W   2118.  .11332441E+04      .25  .55921764E+04          593.                        1
  17 W   2092.  .33452361E+04      .25  .14427344E+05          606.                        1
  16 W   2050.  .18138548E+04      .25  .82804192E+04         1204.                        1
  15 W   1930.  .11042246E+04      .25  .53820484E+04          427.                        1
  14 W   1097.  .74287252E+03      .25  .35204400E+04          336.                        1
  13 W   1040.  .44508772E+03      .25  .23005008E+04          307.                        1
  12 W    979.  .10612625E+04      .25  .47350000E+04          373.                        1
  11 W    946.  .69875544E+03      .25  .32682217E+04          302.                        1
  10 W    878.  .38267458E+03      .25  .19697483E+04          238.                        1
   9 W    572.  .40060011E+03      .25  .18884504E+04          228.                        1
   8 W    536.  .19335186E+03      .25  .10418074E+04          252.                        1
   7 W    388.  .13224861E+03      .25  .72329444E+03          123.                        1
   6 W    361.  .24280616E+03      .25  .11521246E+04          133.                        1
   5 W    349.  .15980334E+03      .25  .81406336E+03          119.                        1
   4 W    245.  .10636202E+03      .25  .54809808E+03          105.                        1
   3 W    232.  .13131788E+03      .25  .64172152E+03           90.                        1
   2 W    138.  .10510562E+03      .25  .48977248E+03           54.                        1
   1 W    103.                                                  39.                        1
```

TABLE 8 LISTING OF SOURCE PROGRAM ARS USHL 2.

```
      DIMENSION X(32), Y(32), C(3),A(3),P(3),R(3),DELQ(3),V2Q(3),V(3),RR
     1(3),AA(3),CC(3)
      COMMON A,P,N,EWS,OBL,OBR,X,Y,NSTA,LET,LL,YDELO,NPASS,AN,RCH,SCH,RC
     1HO,EWS2,EVRT,SLOPOO
  235 ECOMO=0.
      ECOMP = 0.
      YDELO = 0.
      HVO = 0.
      HBR = 0.
      CHBO=0.
      SLOPO=0.
      K = 1
      LN=0
      KODE=1
      PAUSE
      IF(SENSE SWITCH 3)515,516
  515 PUNCH 530,KODE
  516 LN1=0
      READ 220,EI,CSM,SLNEW,HVNEW
      NCSM=CSM
      PUNCH 230,NCSM
   99 READ 1,NSTA,LET,RCH,OBL,OBR,YARK,BEND,SQZE,EVRT,FLAG
      BENO = 0.
      SQZO = 0.
      EINT=EI
      RCHO=RCH
      ECOMOO=ECOMO
      SLOPOO=SLOPO
      AN=1.
      IF(FLAG)2,4,2
    2 READ 3,DA,(C(I),I=1,3),ELEV,DT
      IF(DT)520,520,521
  521 DELT=DT
  520 FLOW=DA*CSM
      FLOW2=FLOW
      IF(ELEV)95,150,95
   95 K = 1
      PUNCH 58, FLOW,ELEV
  154 PUNCH 59,(C(I),I=1,3)
      GO TO 4
  150 PUNCH 152,FLOW
      GO TO 154
    4 DO 6 I = 1,29,4
      II=I+3
      READ 5,NSTA,LET,(X(J),Y(J),J=I,II),EX
      M = I+3
      DO 102 N=I,M
      IF (Y(N)) 102,7,102
```

TABLE 8 (CONTINUED)

```
  102 CONTINUE
  101 IF(EX)7,6,7
    6 CONTINUE
    7 N = N-1
      CHB=Y(1)
      DO 130 I=1,N
      IF(CHB-Y(I))130,130,120
  120 CHB=Y(I)
  130 CONTINUE
      IF(LN)110,205,110
  205 LN=1
      GO TO 139
  110 CHE=CHB-CHBO
      IF(CHE)111,111,112
  111 CHE=0.
  112 SCH=CHE/RCHO
  209 IF(SENSE SWITCH 1)215,226
  215 PRINT 217
      ACCEPT 220,EINT
      RCH=RCHO
      ECOMO=ECOMOO
      SLOPE=SLOPOO
      SLOPO=SLOPE
      AN=1.
  226 NSECS=CHE/EINT
      IF(NSECS-3)227,228,228
  227 NSECS=3
  228 CFAC=NSECS
      RCH=RCH/CFAC
      GO TO 140
  139 CFAC=1
  140 GO TO(10,9),K
C  TEST FOR BRIDGE STATION FLAG
    9 IF(EVRT)11,12,11
   11 EWS = ECOMO
      GO TO 302
   12 EWS=(SLOPE*RCH)+ECOMO
      GO TO 13
   10 EWS = ELEV
  302 EWS2=EWS
   13 DO 14 J = 1,3
      A(J) = 0.
      P(J) = 0.
      R(J) = 0.
      V(J) = 0.
      DELQ(J) = 0.
   14 V2Q(J) = 0.
      LL=0
      CALL AREA
      IF(LL-1)29,99,209
   29 IF(EVRT) 30,32,30
   30 OMEGA = HVO /(EWS - EVRT)
      ALFA = (ASUM - A(1) - A(2) - A(3)) / ASUM
```

TABLE 8 (CONTINUED)

```
    AL4 = ALFA * ALFA * ALFA * ALFA
    HBR = 2.* YARK*(YARK +10.*OMEGA-.6)*(ALFA+15.*AL4) *HVO
    PUNCH 31,NSTA,LET,(A(I),I=1,3),HBR
    GO TO 99
 32 QSUM=0.
    DO 34 J=1,3
    IF(P(J))605,605,33
 33 R(J)=A(J)/P(J)
605 IF(LN1)182,182,180
180 A(J)=(A(J)*AN+AA(J)*(CFAC-AN))/CFAC
    R(J)=(R(J)*AN+RR(J)*(CFAC-AN))/CFAC
    C(J)=(C(J)*AN+CC(J)*(CFAC-AN))/CFAC
    IF(J-2)182,600,182
600 FLOW=(FLOW2*AN+FLOW1*(CFAC-AN))/CFAC
182 IF(C(J))34,34,181
181 V(J)=.01486*(R(J)**.67)/C(J)
    DELQ(J) = V(J) * A(J)
 34 QSUM = DELQ(J) + QSUM
    RATIO = FLOW/ QSUM
    SLOPE = RATIO * RATIO *-.0001
    GO TO (36,35),K
 35 HFRIC = (SLOPE + SLOPO) * .5 * RCH
    GO TO 37
 36 HFRIC = 0.
 37 SUMVQ = 0.
    DO 39 J = 1,3
    IF (V(J))96,96,38
 96 V(J) = 0.
    V2Q(J) = 0.
    GO TO 39
 38 V(J) = V(J) * RATIO
    V2Q(J) = V(J) * V(J) * DELQ(J) * RATIO
 39 SUMVQ = SUMVQ + V2Q(J)
    IF(HVNEW)621,621,620
620 HV1=HVNEW
    HVNEW=0.
    GO TO 625
621 HV1=SUMVQ/(FLOW*64.32)
625 GO TO(97,100),K
 97 ECOMP = ELEV
    GO TO 49
100 DELHV = HV1 - HVO
    IF(DELHV)41,44,40
 41 DELHV = - DELHV
 40 IF(SQZE)44,44,700
700 IF(AN-CFAC)44,80,80
 80 SQZO = DELHV * SQZE
 44 IF(BEND)60,60,701
701 IF(AN-CFAC)60,82,82
 82 BENO = (HV1 + HVO) * .5 * BEND
 60 ECOMP = ECOMO + HFRIC + SQZO + BENO + HVO - HV1
    ETEST = (ECOMP - EWS) -.1
    IF(ETEST) 47, 49,48
```

TABLE 8 (CONTINUED)

```
 47 ETEST = EWS - ECOMP -.1
    IF(ETEST) 49, 49, 48
 48 EWS = ECOMP + (EWS - ECOMP) * .5
    GO TO 13
 49 IF(SLNEW)301,301,300
300 SLOPE=SLNEW
    SLNEW=0.
301 SLOPO=SLOPE
    HVO = HV1
    ECOMO = ECOMP
    CHBO=CHB
    ASUM = A(1) + A(2) + A(3)
    IF(HBR)57,57,81
 81 IF(AN-CFAC)83,55,55
 55 ELEV = ECOMP + HBR
    HBR=0.
    K = 1
    GO TO 10
 57 HBR=0.
 83 K=2
    AN=AN+1.
    NPASS=0
    IF(AN-CFAC)9,650,280
650 IF(EWS-CHB)651,9,9
651 EWS=CHB
    GO TO 13
280 IF(LN1)499,499,500
499 LN1=1
    GO TO 510
500 IF(SENSE SWITCH 3)505,510
505 A1=0.
    A2=0.
    DO 507 I=1,3
    A1=A1+A(I)
507 A2=A2+AA(I)
    AVGA=(A1+A2)/2.
    S=RCHO*AVGA/3600.
    ROF1=(FLOW1/2.)+S/DELT
    PUNCH 540,NSTAO,LET,FLOW1,S,DELT,ROF1,A2,KODE
    IF(NSTA-1)510,508,510
508 PUNCH 541,NSTA,LET,FLOW2,A1,KODE
510 DO 85 J=1,3
    RR(J)=R(J)
    AA(J)=A(J)
 85 CC(J)=C(J)
    FLOW1=FLOW2
    NSTAO=NSTA
    RCH=RCHO
    PUNCH 52,RCH,NSTA,LET,SLOPE,(V(I),I=1,3),HV1,ECOMP
    PUNCH 53,HFRIC,(A(I),I=1,3),BENO,EWS,(R(I),I=1,3),SQZO
    IF(NSTA-1)99,240,99
240 PRINT 234,NCSM
    PAUSE
```

TABLE 8 (CONTINUED)

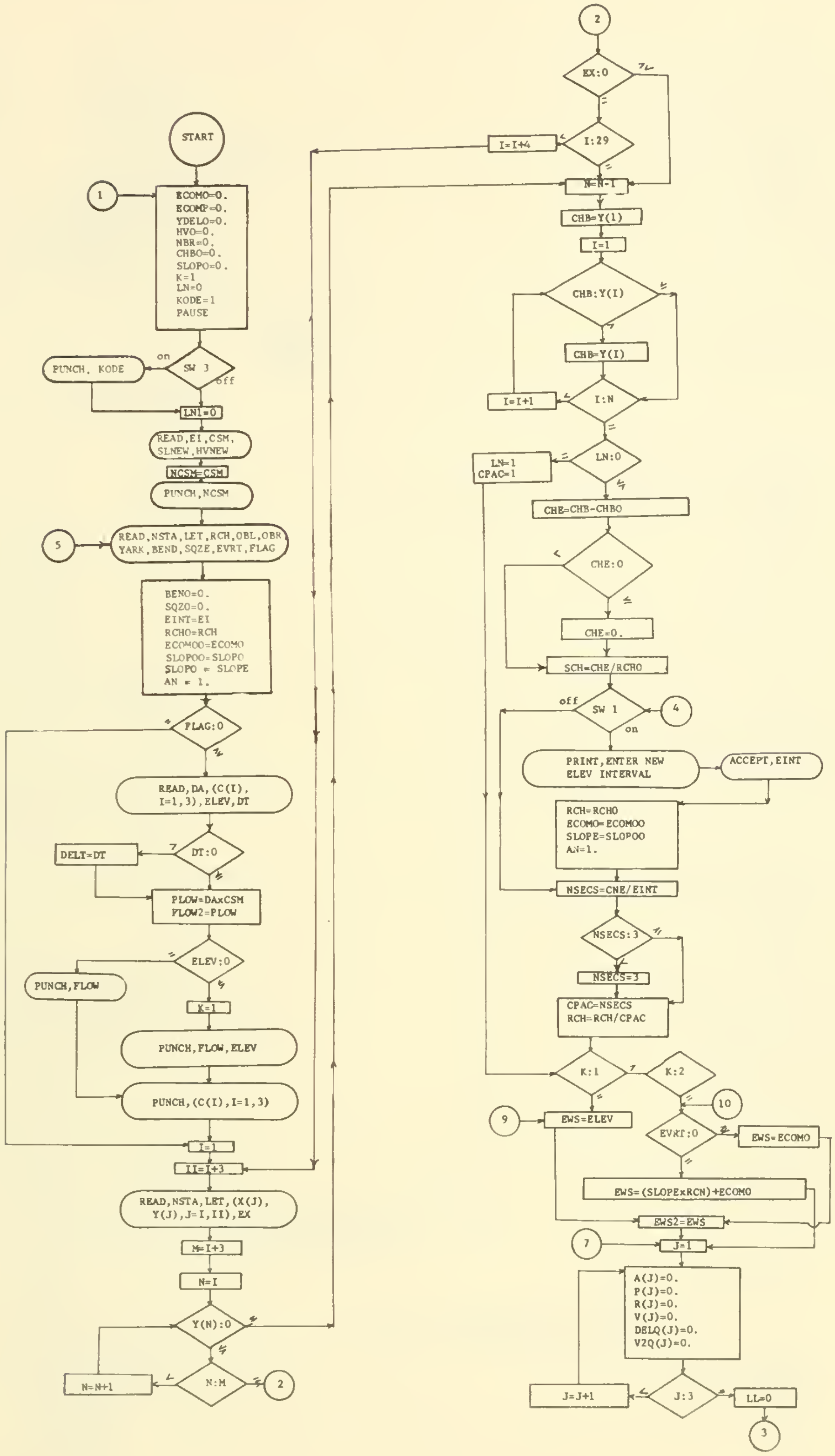
```
      GO TO 235
    1 FORMAT(I4,A2,F5.0,2F4.0,3F3.2,F5.1,F1.0)
    3 FORMAT(6X,F6.2,3F3.3,F6.2,F4.2)
    5 FORMAT(I4,A2,8F5.1,F1.0)
   31 FORMAT(14HBRIDGE SECTION/I5,A2,10X,F10.0,2F8.0,F10.2)
   58 FORMAT(6X4HFLOW,F9.0,5X19HSTARTING W.S. ELEV.,F9.2)
   52 FORMAT(4HRCH=,F7.0/I5,A2,4X,F9.7,1X,3(2X,F6.2),3X,F5.2,3X,F8.2)
   53 FORMAT(9X,F6.2,2X,F10.0,2F8.0,F10.2,F11.2/21X,4F8.2)
   59 FORMAT(6X,8HN VALUES,2X,3F6.3)
  152 FORMAT(6X4HFLOW,F9.0)
  217 FORMAT(23HENTER NEW ELEV INTERVAL)
  220 FORMAT(F3.2,F6.0,F7.7,F4.2)
  230 FORMAT(I5,12H CSM PROFILE//)
  234 FORMAT(6HEND OF,I5,49H CSM PROFILE-LOAD DATA-PUSH START FOR NEXT P
     1ROFIL,1HE)
  530 FORMAT(49H STATION   CFS          S          DFLT (O/2 + S/,14HDEL
     1T)     AREA,15X,I2)
  540 FORMAT(I5,A2,F9.0,1X,E14.8,F8.2,1X,E14.8,F11.0,13X,I2)
  541 FORMAT(I5,A2,F9.0,38X,F11.0,13X,I2)
      END
```

```
      SUBROUTINE AREA
      DIMENSION A(3),P(3),X(32),Y(32)
      COMMON A,P,N,EWS,OBL,OBR,X,Y,NSTA,LET,LL,YDELO,NPASS,AN,RCH,SCH,RC
     1HO,EWS2,EVRT,SLOPOO
      XBASF(E,G)=E-G
      XYARF(E,G,H)=E*G/H
      XATSF(E,G,H)=E*(G-H)
      XWPPF(E,G,H,D)=SQRTF((E-G)**2+(H-D)**2)
      IF(RCHO)205,205,197
  197 IF(EVRT)205,199,205
  199 EWS2=(RCHO-AN*RCH)*SCH+EWS
      IF(EWS2-Y(1))200,200,201
  200 IF(EWS2-Y(N))205,205,202
  201 LM=1
      GO TO 203
  202 LM=N
  203 NPASS=NPASS+1
      IF(NPASS-2)204,280,280
  204 EWS2=Y(LM)
  205 YDELO=0.
      DO 270 I=1,N
      IF(OBL-X(I))212,210,210
  210 J=1
      GO TO 220
```

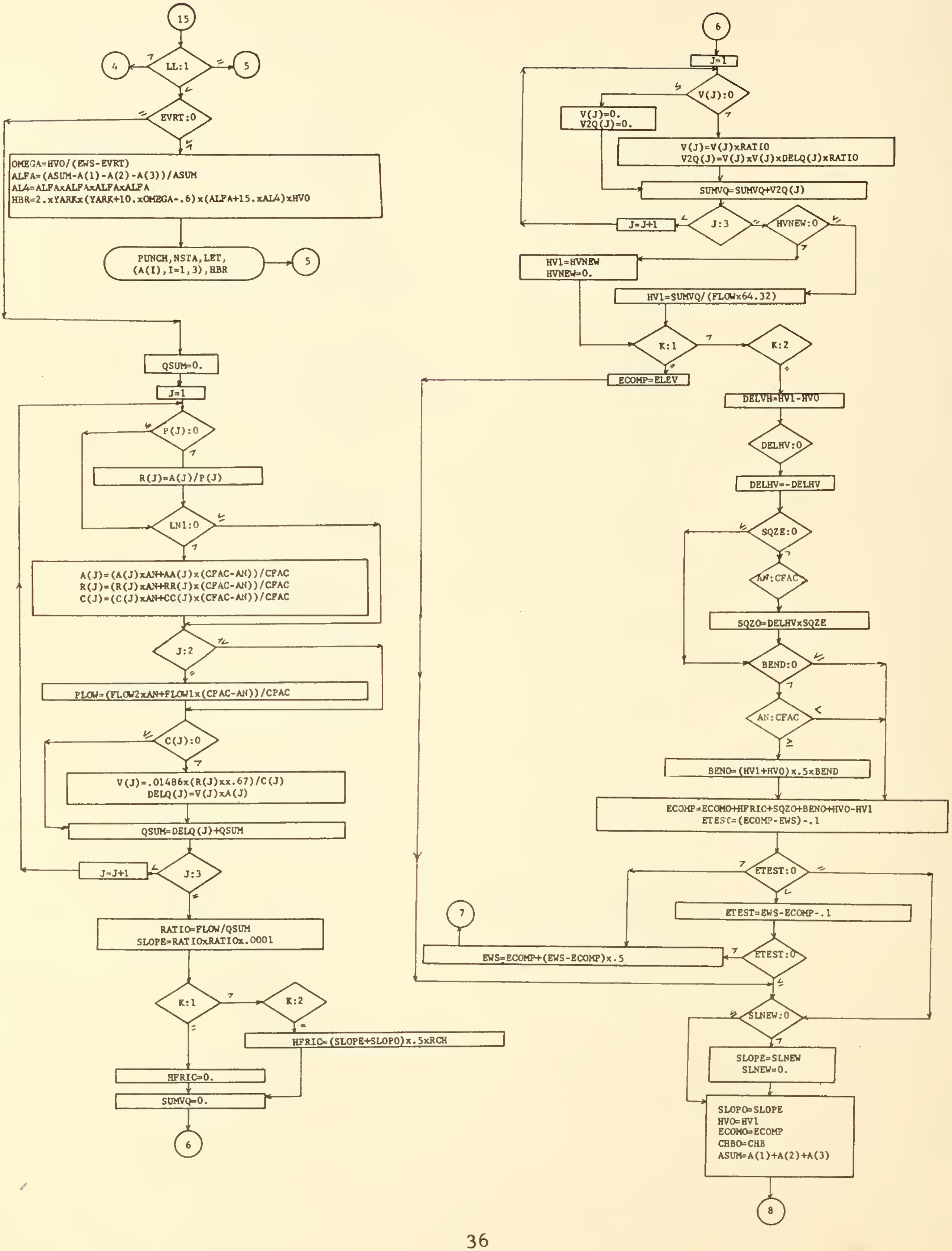
TABLE 8 (CONTINUED)

```
212 IF(OBR-X(I))216,215,215
215 J=2
    GO TO 220
216 J=3
220 YDEL=XBASF(EWS2,Y(I))
    IF(YDEL)225,225,230
225 IF(YDELO)270,270,250
230 IF(YDELO)235,265,258
235 K=1
236 B=XBASF(X(I),X(I-1))
    C=XBASF(Y(I),Y(I-1))
240 GO TO(245,255,260,264,267),K
245 XWS=X(I)+XYARF(B,YDEL,C)
    A(J)=A(J)+XATSF(YDEL/2.,X(I),XWS)
    P(J)=P(J)+XWPPF(X(I),XWS,YDEL,0.)
    GO TO 270
250 K=2
    GO TO 236
255 XWS=X(I)+XYARF(B,YDEL,C)
    A(J)=A(J)+XATSF(YDELO/2.,XWS,X(I-1))
    P(J)=P(J)+XWPPF(XWS,X(I-1),YDELO,0.)
    GO TO 270
258 IF(Y(I)-Y(I-1))259,263,263
259 K=3
    GO TO 236
260 A(J)=A(J)+XYARF(B,C,-2.)+XYARF(B,YDELO,1.)
    P(J)=P(J)+XWPPF(B,0.,C,0.)
    GO TO 270
263 K=4
    GO TO 236
264 A(J)=A(J)+XYARF(B,C,2.)+XYARF(B,YDEL,1.)
    P(J)=P(J)+XWPPF(B,0.,C,0.)
    GO TO 270
265 K=5
    GO TO 236
267 A(J)=A(J)+XYARF(B,C,-2.)
    P(J)=P(J)+XWPPF(B,0.,C,0.)
270 YDELO=YDEL
    GO TO 285
280 NPASS=0
    PRINT 300,NSTA,LET
    PAUSE
    IF(SENSE SWITCH 1)283,284
283 LL=2
    GO TO 285
284 LL=1
285 RETURN
300 FORMAT(21HEXCEEDS SURVEY LIMITS,I4,A2,2X,49HTURN SW 1 ON FOR RERUN
   1 WITH SHORTER REACH LENGTH /33HOFF CONTINUES UPSTREAM,PUSH START)
    END
```

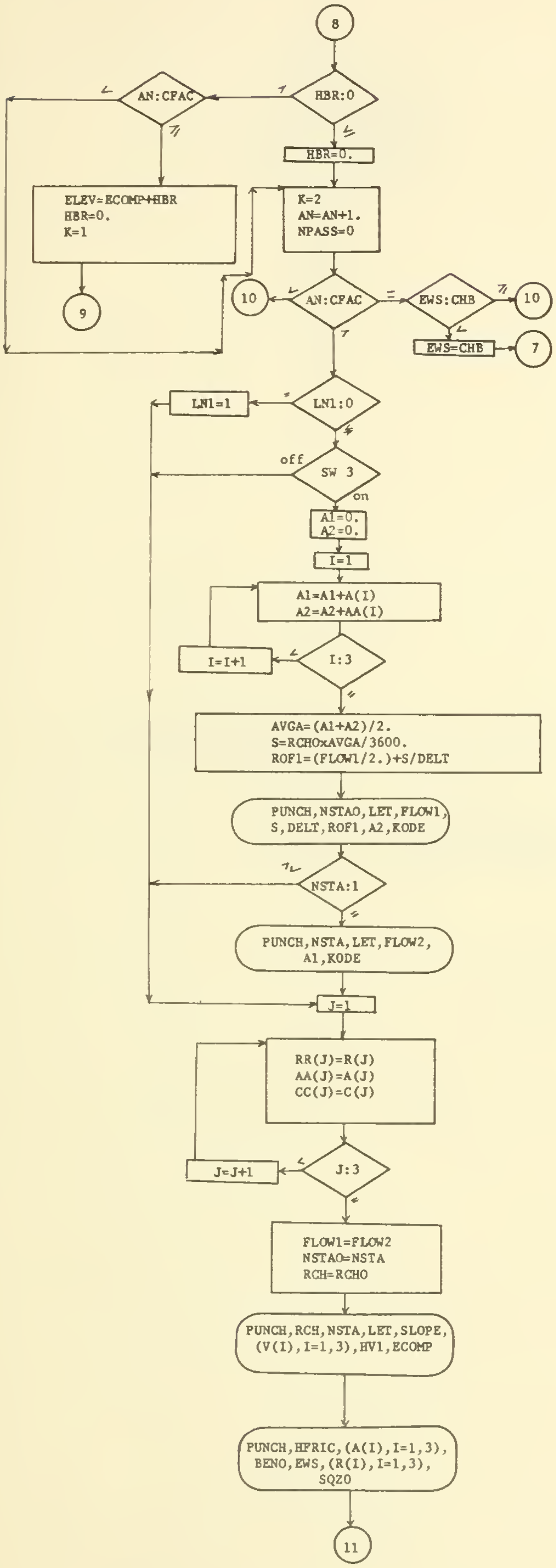
Detailed Flow Diagram--Computer Program USHL #2

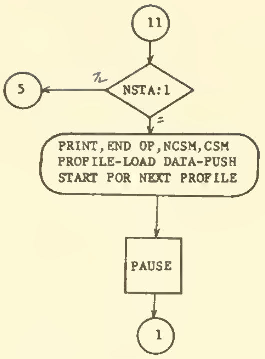


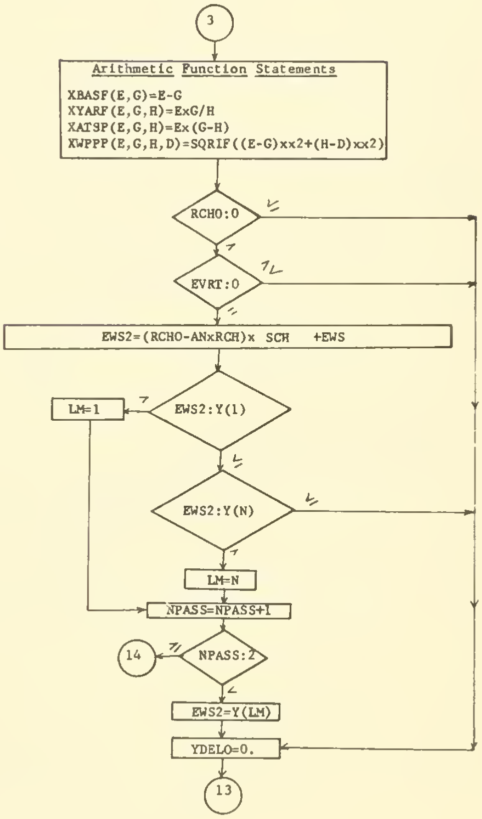
Detailed Flow Diagram (continued)



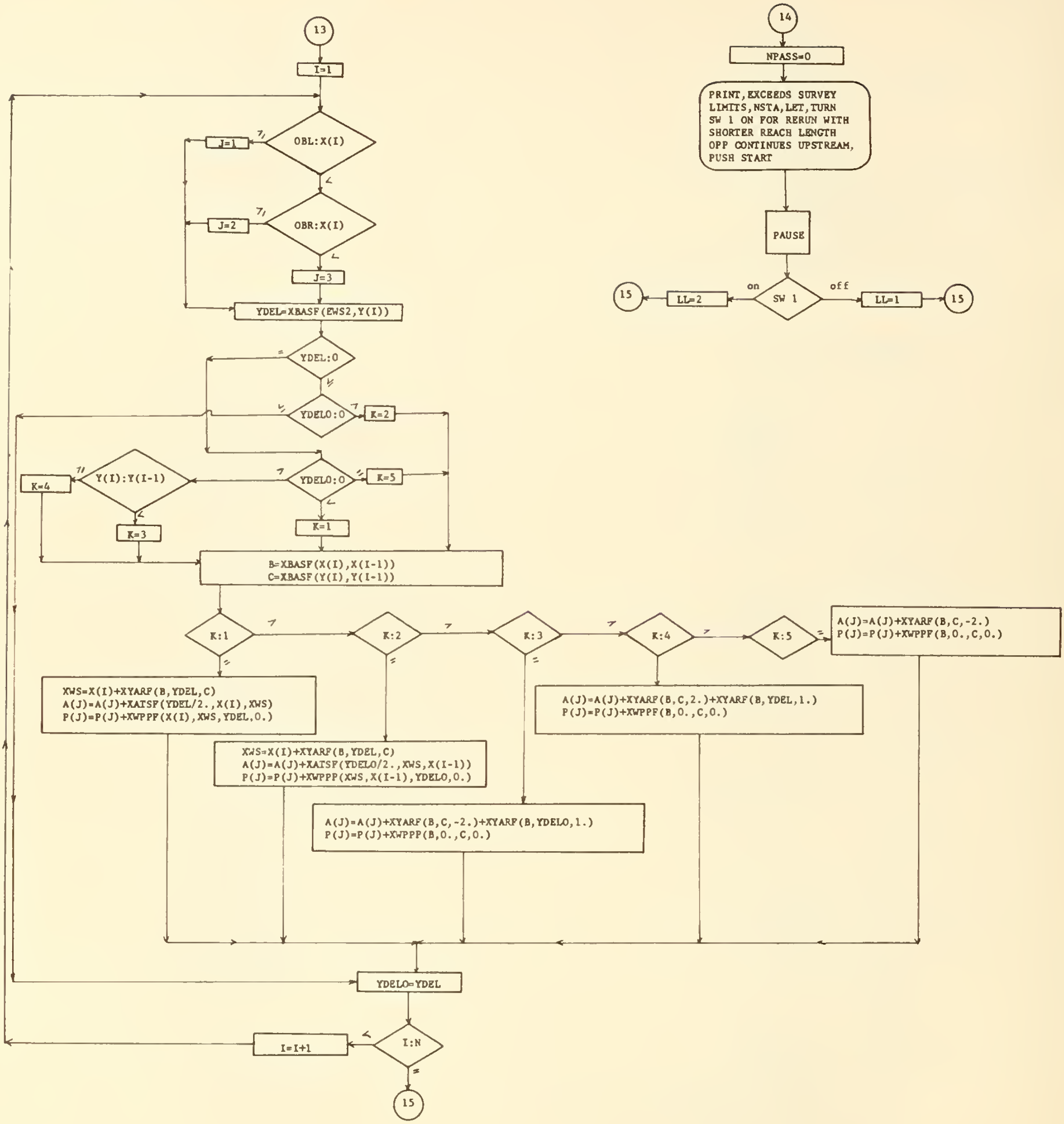
Detailed Flow Diagram (continued)







Detailed Flow Diagram (continued)


13
I=1
OBL:X(I)
>
J=1
<
OBR:X(I)
>
J=2
<
J=3
YDEL=XBASF(EWS2,Y(I))
YDEL:0
=
≠
YDELO:0
≤
>
K=2
YDELO:0
>
≤
K=5
<
K=1
Y(I):Y(I-1)
>
K=4
<
K=3
B=XBASF(X(I),X(I-1))
C=XBASF(Y(I),Y(I-1))
K:1
>
=
K:2
>
=
K:3
>
=
K:4
>
K:5
=
A(J)=A(J)+XYARF(B,C,-2.)
P(J)=P(J)+XWPPF(B,0.,C,0.)
XWS=X(I)+XYARF(B,YDEL,C)
A(J)=A(J)+XATSF(YDEL/2.,X(I),XWS)
P(J)=P(J)+XWPPF(X(I),XWS,YDEL,0.)
XWS=X(I)+XYARF(B,YDEL,C)
A(J)=A(J)+XATSF(YDELO/2.,XWS,X(I-1))
P(J)=P(J)+XWPPP(XWS,X(I-1),YDELO,0.)
A(J)=A(J)+XYARF(B,C,-2.)+XYARF(B,YDELO,1.)
P(J)=P(J)+XWPPP(B,0.,C,0.)
A(J)=A(J)+XYARF(B,C,2.)+XYARF(B,YDEL,1.)
P(J)=P(J)+XWPPF(B,0.,C,0.)
YDELO=YDEL
I:N
<
I=I+1
=
15
14
NPASS=0
PRINT, EXCEEDS SURVEY LIMITS, NSTA, LET, TURN SW 1 ON FOR RERUN WITH SHORTER REACH LENGTH OPP CONTINUES UPSTREAM, PUSH START
PAUSE
SW 1
on
off
LL=2
LL=1
15
15

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